Semiclassical Approximations And Predictability In Ocean Acoustics

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LONG-TERM GOAL

Our long-term goal is to improve our understanding of the physics of the forward scattering of underwater sound. Of particular interest is understanding limitations on the predictability of underwater sound fields, especially using semiclassical (ray-based) methods. Improving our understanding of the mechanism(s) that contribute to the loss of predictability will lead to improved predictive models.

OBJECTIVES

The scientific objective of this work is to understand limitations on the predictability of acoustic wavefields in realistic (range-dependent) ocean environments. Both full wave and semiclassical predictive models are of interest. Both cw and broadband wavefields are of interest. We seek to both develop improved predictive acoustic models and to understand their limitations.

APPROACH

Using semiclassical methods, ideas relating to ray chaos provide a framework for studying predictability. Wavefield behavior in the ray limit is explored numerically and, whenever possible, analytically. The extent to which limitations on predictability carry over to finite frequency wavefields are then explored numerically, generally with parabolic equation based models. Both deterministic and stochastic models are of interest. Comparisons with data are made whenever possible.

Several tools have recently been developed and/or extended for use in our work: Tappert's co-insensitive PE model; the MaChl algorithm (Brown, 1994) for finite frequency ray-based wavefield predictions; a new stochastic ray model (Brown and Viechnicki, 1998) to model scattering by internal waves; and a new efficient algorithm to generate realistic internal wave induced sound speed perturbation fields (Colosi and Brown, 1998).

This work is being done in loose collaboration with the following individuals: F. Tappert (U. Miami; parabolic wave equations, waves in random media, ray chaos); M. Wolfson (Washington State U.; numerical modelling, waves in random media, ray chaos); G. Zaslavsky (Courant Institute; chaos in dynamical systems, stochastic methods, quantum chaos); S. Tomsovic (Washington State U.; quantum chaos and semiclassical breakdown); and J. Colosi (WHOI; internal waves, long-range propagation).

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WORK COMPLETED

The principal accomplishment of the recent years are 1) the development and numerical implementation of stochastic ray theory to describe and model the scattering of sound by internal waves in deep ocean environments; 2) the development (with J. Colosi at WHOI) of a new efficient, accurate, and robust algorithm to compute internal-wave-induced sound speed perturbation fields; 3) incorporation of this internal wave model into both ray and full wave propagation models; 4) demonstration that for a large class of problems involving boundary interactions, ray phase errors are inversely proportional to frequency and increase linearly with range; and 5) demonstration (Brown, 1998) that, in the ray limit, islands of stability in phase space exist when the environment is almost stratified and has quasiperiodic range dependence.

RESULTS

Stochastic ray theory and the new technique to compute internal-wave-induced sound speed perturbation fields are important new tools which can be used to address fundamental questions relating to the predictability of long-range sound propagation in deep ocean environments. The work relating to the structure of phase space provides critically important insight into - and a mathematical framework for the study of - wave propagation in environments with nontrivial range-dependence. Our predictability studies show that, even in the presence of chaotic ray motion, semiclassical wavefield representations accurately predict many important features of underwater acoustic wavefields.

IMPACT/APPLICATION

Our work gives insight into the limitations on the predictability of underwater sound fields. This is an important basic science issue which impacts all systems applications which require accurate predictions of underwater sound fields.

TRANSITIONS

The PI collaborates informally with the investigators listed above, ATOC investigators, and others. This includes the sharing of both ideas and software. It is not known whether any software produced by the PI has been used to address any applied Navy problems.

RELATED PROJECTS

This work is closely related to the ATOC project and the ONR-funded work being performed by P. Worcester (SIO), J. Colosi (WHOI), M. Wolfson (WSU), J. Spiesberger (PSU), S. Tomsovic (WSU), G. Zaslavsky (CIMS) and F. Tappert (U. Miami). All of these projects are concerned with aspects of long-range propagation.

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Colosi, J.A., and M.G. Brown, 1998, Efficient numerical simulation of stochastic internal wave induced sound speed perturbation fields, J. Acoust. Soc. Am. 103, 2232-2235.

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PUBLICATIONS

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